

MICROVOLTMETER
and
AMPLIFIER
MODEL 202B

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KIN TEL

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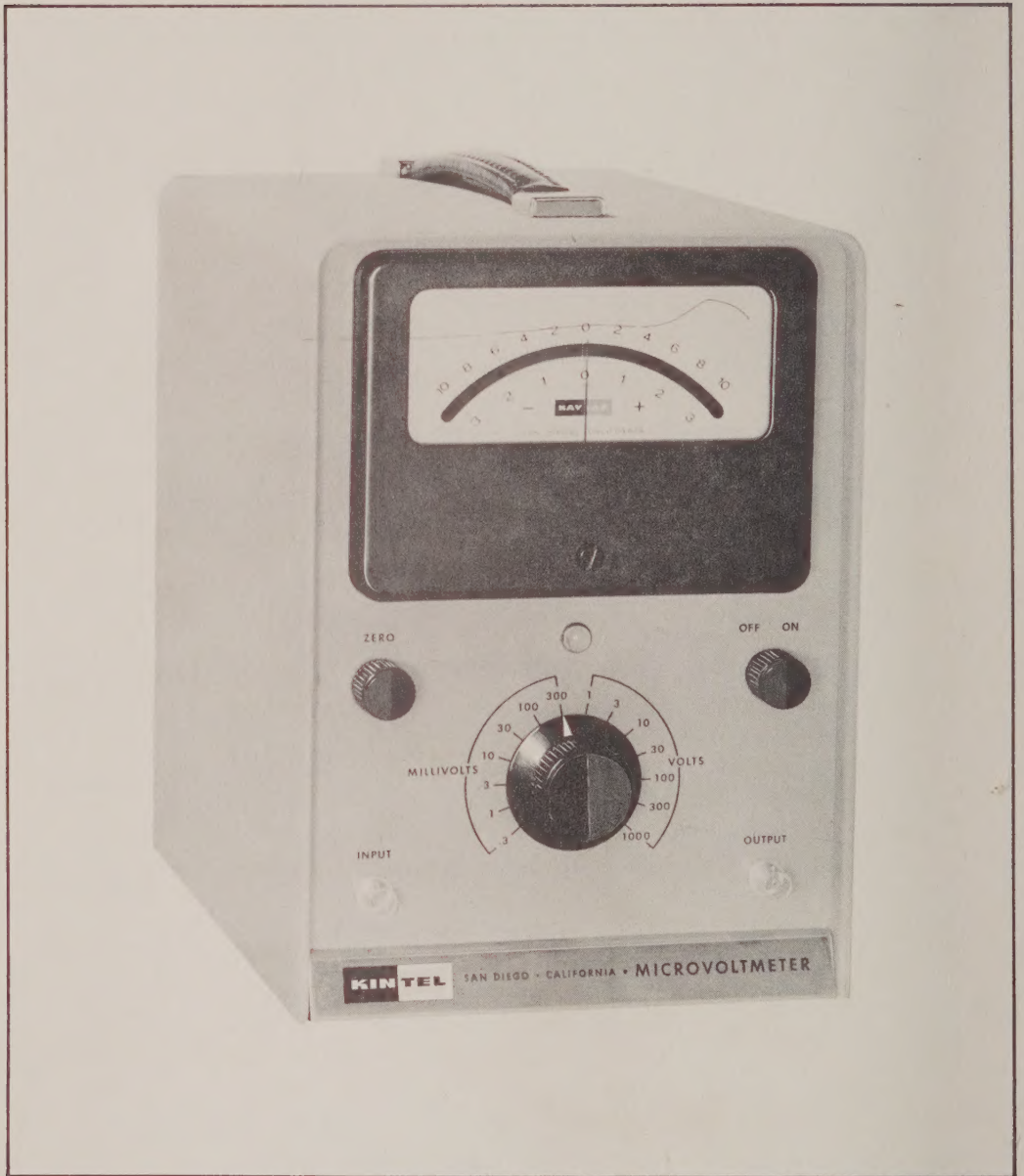


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AMPLIFIER
MODEL 202B

TECHNICAL MANUAL

Code No. 3X-6

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MODEL 202B MICROVOLTMMETER

TABLE OF CONTENTS

MODEL 202B

SECTION 1	GENERAL
1.1	DESCRIPTION
1.2	APPLICATIONS
1.3	SPECIFICATIONS
SECTION 2	OPERATION
2.1	TURN ON PROCEDURE
2.1.1	Noise Characteristics
2.2	PRECAUTIONS
2.3	USE AS AN AMPLIFIER
SECTION 3	CIRCUIT DESCRIPTION
3.1	THE POWER SUPPLY
3.2	THEORY OF FEEDBACK AMPLIFIERS
3.3	THE AMPLIFIER SYSTEM
3.3.1	General Description
3.3.2	The Chopper Amplifier
3.3.3	The DC Amplifier
3.3.4	The Feedback Circuit
3.4	CIRCUIT DETAILS
3.4.1	Input and Range Switching Circuit
3.4.2	The Chopper Amplifier
3.4.3	The DC Amplifier and Output Circuit
SECTION 4	MAINTENANCE
4.1	PARTS LOCATION
4.1.1	Precautions
4.2	PREVENTIVE MAINTENANCE
4.3	TROUBLE SHOOTING PROCEDURE
4.3.1	AC Amplifier
4.3.2	Power Supply
4.3.3	Meter Circuitry
4.3.4	Feedback and Attenuation
4.3.5	DC Amplifier

APPENDIX	PARTS LIST
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SECTION 1

GENERAL

1.1 DESCRIPTION

The KIN TEL Model 202B is a combination DC microvoltmeter and amplifier. KIN TEL's proven chopper circuitry provides high sensitivity with previously unobtainable drift-free stability and high input impedance. The instrument features an exceptionally wide range of measurements. Fourteen voltage ranges cover from 300 μv full scale to 1000 volts full scale. The zero-center meter face indicates polarity on a mirrored scale, which covers all ranges. The amplifier has a maximum gain of 70 db to an output connector on the front panel, providing for its use as a low-drift DC amplifier with high gain and very high input impedance. The physical design utilizes etched circuitry for compactness, neatness, and convenient parts location.

1.2 APPLICATIONS

The Model 202B is an extremely useful instrument in electronic research and development, transistor production or circuit design, medical and biological research, geophysics, metallurgy, chemistry, or wherever accurate amplification or measurement of very small DC voltages is required. Because of the high input impedance, the instrument is useful as a recorder driver, where the recorder does not have the required high input impedance or sensitivity. The very wide voltage range of the instrument makes it most versatile as a general purpose DC vacuum tube voltmeter.

1.3 SPECIFICATIONS

Accuracy on all ranges	3% of full scale
Maximum gain as amplifier	70 db
Output voltage	1 volt across 1000 Ω or more, full scale
Output impedance	Less than 5 Ω
Drift (after 15 min. warm-up).	15 μv equivalent input on the 300 μv range
Isolation resistance in probe.	1 megohm
Power required	105-125 volts, 60 cycles, 30 watts (approximate)
Maximum internal noise (bounce)	$\pm 10 \mu\text{v}$ equivalent input on the 300 μv range (The bounce occurs about a mean point which is readily discernible, and there is no possibility of its being "added" to the meter indication as an error. See Paragraph 2.1.1)
Input connector.	UG-625/U, normally used for mating probe assembly
Output connector	UG-625/U
Dimensions.	11" high, 7 1/2" wide, 11" deep
Net weight	14 pounds

(over)

VOLTAGE RANGE

0/300	μ v
0/1/3/10	mv
0/30	mv
0/100/300	mv
0/1/3/10/30	v
0/100/300/1000	v

INPUT IMPEDANCE

10 megohms
10 megohms
30 megohms
100 megohms
100 megohms
100 megohms

Specifications subject to change without notice.

SECTION 2

OPERATION

2.1 TURN-ON PROCEDURE

The instrument should be connected to a 117 volt, 60 cycle AC source and allowed a warm-up period of at least one minute. The zero control may then be adjusted. To do this, short the input, switch to the 300 μv range, and adjust the control on the front panel. The zero setting will then be correct for all ranges. It may be necessary to readjust the zero control after approximately fifteen minutes of operation. This control may be adjusted without shorting the input and without switching to the lower range. However, the adjustment obtained without these precautions may not hold precisely for all other ranges. The zero adjustment is necessary only to take care of long term changes in the circuits of the instrument. It is not necessary to readjust for zero each time the range switch is operated, although on the most sensitive ranges additional accuracy may sometimes be obtained by so doing.

2.1.1 Noise Characteristics

The Model 202B, in common with all electronic instruments used for measurement, has an inherent noise level. This noise level is determined by factors such as input impedance, bandwidth, operating temperature, and, on line operated devices, internal pick-up. The power level of this noise is so low that it does not affect instruments of average sensitivity. The Model 202B has a power sensitivity comparable to the finest galvanometer. Consequently it is possible to observe the input noise on the more sensitive ranges. This noise appears as a meter "bounce". For other than the lowest ranges, the net gain is reduced, and the "bounce" is reduced accordingly. Peak magnitude of bounce about a mean point on the Model 202B should be less than $\pm 10 \mu\text{v}$ equivalent input. Typically, the bounce has a peak amplitude of $\pm 3 \mu\text{v}$. Line transients may cause an additional $\pm 5 \mu\text{v}$. This should be checked on the .3 mv range with the input probe shorted.

Normally, the probe that is provided with the instrument will provide the best performance. It is permissible to substitute a different probe for special applications. However, a 1 megohm, 5 per cent, isolation resistor must still be used to retain accuracy. If cable capacity is not important, the isolation resistor may be installed inside the switch compartment. The probe cable provided with the instrument is Amphenol low-noise coaxial cable. Other types which are not low-noise may introduce transients when the cable is flexed.

2.2 PRECAUTIONS

The Model 202B will withstand severe overloading of the input. However, DO NOT EXCEED 1,500 VOLTS PEAK INPUT under any condition. Otherwise, maximum input should be restricted to 100 times full scale rating being used; e.g., .1 volt on the 1 mv range or 100 volts on the 1 volt range. Even these amounts will produce a temporary zero shift and the meter will stay at full scale deflection for several seconds.

The normal precautions that must be observed when using any type of voltmeter should be observed with the Model 202B. When measuring unknown values of voltage, always start on the highest range and decrease the range setting to the appropriate range.

2.3 USE AS AMPLIFIER

If the instrument is to be used as an amplifier, the output signal is taken from the front panel connector, which is connected directly to the DC amplifier output. Maximum output of the amplifier for maximum input on any range is 1 volt. Minimum permissible load resistance is 1000 ohms. Therefore, if an external indicating device is used, it must be capable of handling a plus or minus one volt signal and present not less than a 1000 ohm load to the amplifier output.

SECTION 3

CIRCUIT DESCRIPTION

3.1 THE POWER SUPPLY

The power supply of the KIN TEL Model 202B consists of a transformer with a fused primary isolated from the AC line by an RF choke and by-pass capacitors, and with four secondaries. The third wire on the AC line connects the chassis common ground to earth ground. The fuse is a 3/10 amp Slo-Blo type.

On the schematic diagram, the top secondary provides properly phased AC to drive diodes CR1 and CR2 at the output of the chopper amplifier. The second winding supplies a high voltage full wave rectifier whose output is connected across two series connected voltage regulator tubes. The point where the two tubes are connected is grounded. This divides the voltage to provide minus 105 and plus 150 volts. Note the use of a cardboard cover on the filter capacitor of the high voltage power supply. Since the case of this capacitor, C1A-B, is 105 volts below ground, care must be taken to see that it is properly insulated. The third winding supplies AC heater voltage to all tubes (except V1), pilot light voltage, and properly phased energizing voltage to the chopper. The bottom winding supplies heater voltage which is rectified by two 1N91 diodes to supply DC to the heater of the first AC amplifier tube, V1. This minimizes hum pick-up in this low level amplifier.

3.2 THEORY OF FEEDBACK AMPLIFIERS.

The KIN TEL Microvoltmeter and Amplifier, Model 202B, consists primarily of an amplifier using large amounts of feedback. The block diagram, Figure 3-1, indicates the general nature of the system.

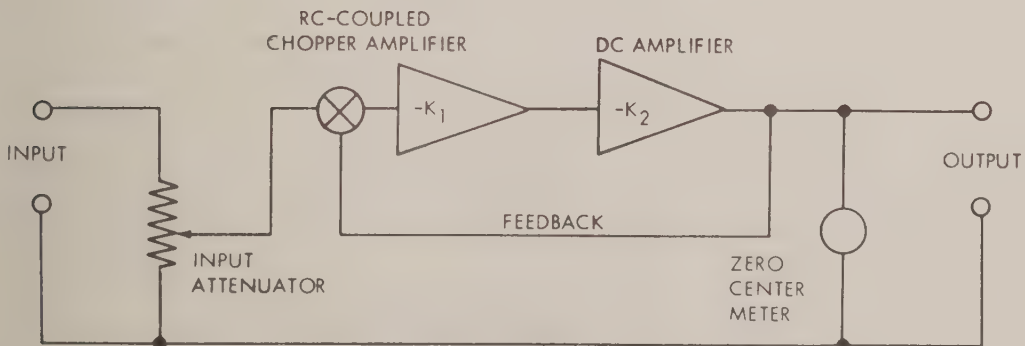


FIGURE 3-1

The minus (-) sign in front of K_1 and K_2 indicates that the phase is being inverted. The forward gain of the system is approximately 116 db. For a maximum net gain of 70db there is then 46db of feedback. From the first through the third ranges, the feedback is increased in

steps of 10 db for a net gain of 50 db on the third and all higher ranges. Less feedback is used in steps 1 and 2 to provide more gain for the low amplitude input signals being measured.

The purpose of the feedback is to stabilize the gain. It can be shown that where a large amount of feedback is used, the accuracy of the gain is nearly independent of tube and component variation:

For positive amplifier (+K) as shown below, where the polarity of the feedback is such as to reduce gain (negative feedback), the net gain with feedback is:

$$A_n = \frac{E_o}{E_{in}} = \frac{E_o}{E'_{in} + \beta E_o} \quad (1)$$

where

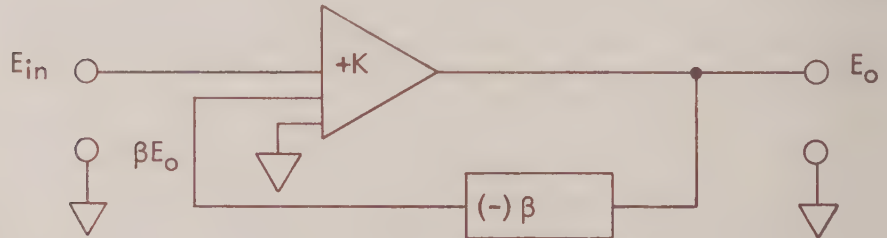
A_n = net gain

E_o = output voltage

E_{in} = input voltage = $E'_{in} + \beta E_o$

E'_{in} = net input to amplifier

β = the fraction of the output voltage being fed back.



but

$$E_o = K E'_{in} \quad (2)$$

where

K = amplifier gain without feedback

Combining (1) and (2)

$$A_n = \frac{K E'_{in}}{E'_{in} + \beta K E'_{in}} = \frac{K E'_{in}}{E'_{in} (1 + \beta K)} = \frac{K}{1 + \beta K} \quad (3)$$

It may be noted that this expression is generally given as

$$A_n = \frac{K}{1 - \beta K} \quad (3a)$$

and β is assumed negative if the polarities are such that the feedback acts to reduce the gain. In either case, the result is the same. The gain reduction factor is termed the feedback factor, and is equal to the product of β times K .

$$F = \beta K \quad (4)$$

where

F = feedback factor

β = the fraction of the output voltage being fed back

K = amplifier gain without feedback.

Substituting (4) in (3a) gives

$$A_n = \frac{K}{1-F} \quad (4a)$$

Now, if the feedback factor (the product of β times K) is much greater than 1, (3) may be rewritten

$$A_n \cong \frac{K}{F} \cong \frac{K}{\beta K} \cong \frac{1}{\beta} \quad (5)$$

with an error which becomes less and less as the feedback factor (the product of β times K) increases.

The result is that the gain of a system with large amounts of feedback and a high amplifier gain (i.e., $\beta K \gg 1$) is, for all practical purposes, independent of all factors except the accuracy of the feedback network.

Since the feedback network determining the feedback fraction (β) consists of precision resistors in the Model 202B, the accuracy of the gain of the amplifier is maintained to the accuracy of the precision resistors.

3.3 THE AMPLIFIER SYSTEM

3.3.1 General Description

The amplifier system actually consists of two amplifiers: a chopper amplifier and a DC amplifier. The chopper amplifier is on the input side and feeds the DC amplifier on the output side. The chopper amplifier is more stable for amplifying low level DC than a straight DC amplifier.

To prevent oscillations due to feedback loops created by minute voltage differentials between different chassis areas, all grounds in the amplifier are connected to a circuit common grounded at the input and also brought out to an external earth ground through a third lug on the AC power plug.

Since the KIN TEL Microvoltmeter must indicate the magnitude of extremely small DC signals, great amplification is necessary before the signal can be used to actuate a conventional DC microammeter movement. It was found that the gain could be rigidly fixed by the use of a large amount of feedback, thus adapting an electronic amplifier to measurement purposes. A conventional direct coupled DC amplifier cannot be used, however, because of the trouble encountered with drift and grid currents. If grid current is allowed to flow into the input system, an apparent input signal is developed which results in an erroneous output. In the conventional DC amplifier, drift may also be caused by changes in the direct current flowing through the tubes. Such changes can be caused by small changes in heater voltage or by normal tube aging resulting in changes in the emission characteristics of the tubes.

These difficulties may be overcome with the use of the chopper amplifier, since it reduces the effects of grid current flow in the input circuit, and plate current drift, to a negligible amount by the use of coupling capacitors.

Figure 3-2 shows how the effects of grid currents and drifting plate current would give an erroneous output in a conventional DC amplifier with very small DC input, and how these effects are overcome with the chopper amplifier. Part A shows greatly magnified plate voltage drift in a DC amplifier with grid shorted to cathode. This plate voltage drift is due to changes in plate current. Part B shows the same voltage drift, but at a different level due to current flowing through the grid resistance and changing the bias. Part C shows plate voltage with a small plus DC voltage applied at the grid. Plate voltage drifts as before, but again at a different level. Note that the plate voltage change caused by the small input signal is of the same order of magnitude as the changes caused by grid current and plate current drift. Unless a much larger input signal is used, DC plate voltage change will not be dependent on signal voltage change, and the amplifier will give erroneous readings. Part D shows plate voltage with a small DC voltage being switched on and off at the grid. Note that while drift is still apparent, the rate of change of the square wave component is constant. Part E shows the voltage of part D as it would appear at the grid of the following stage in a capacity-coupled amplifier. Since the coupling condensers have blocked the drifting DC component, all that remains is the amplified input square wave proportional to the small DC input, and the amplifier is a success! Long term drift in the system due to thermal effects and circuit aging can be compensated for when necessary by use of a zero adjustment.

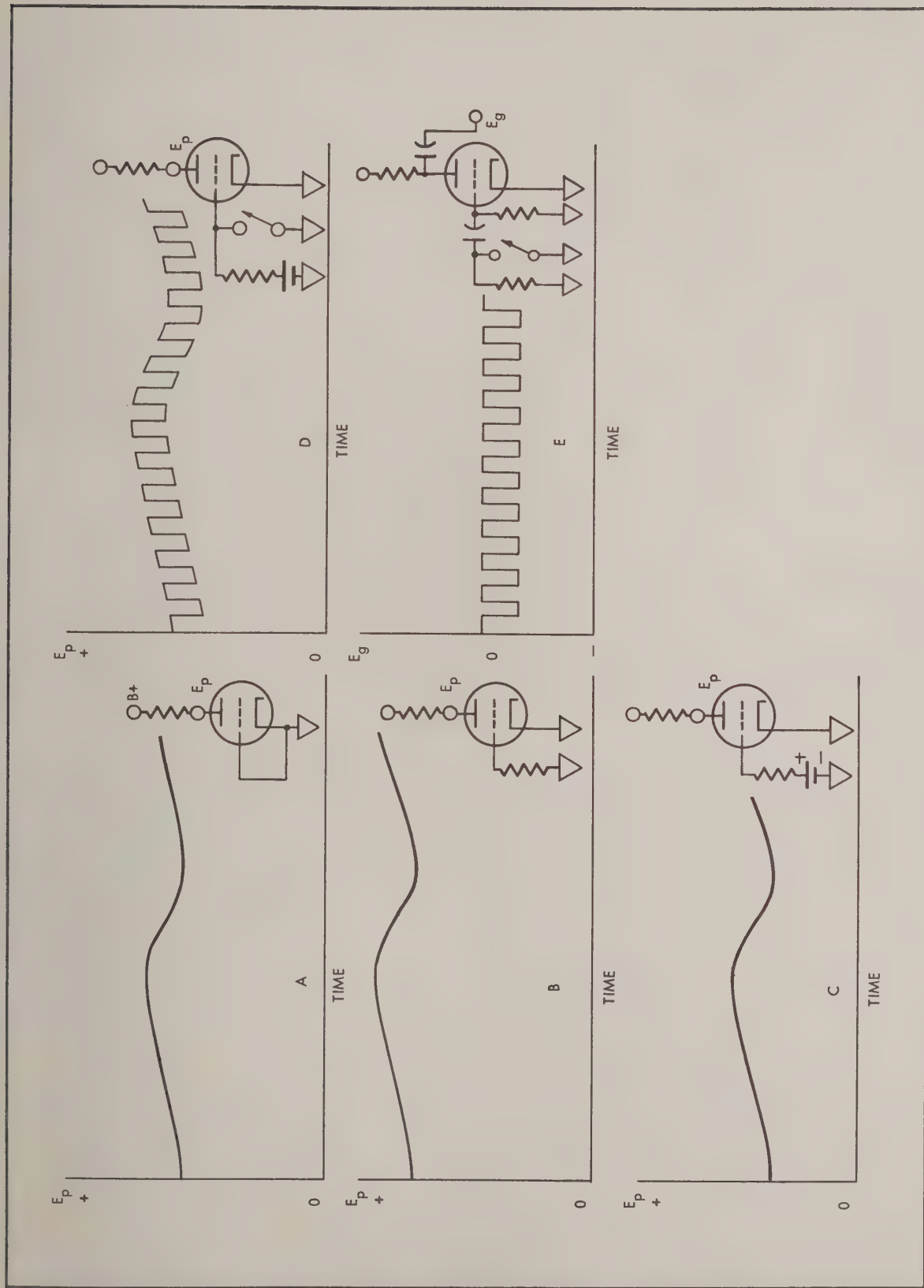


FIGURE 3-2

3.3.2 The Chopper Amplifier

Figure 3-3 represents the basic chopper amplifier circuit used in the Model 202B.

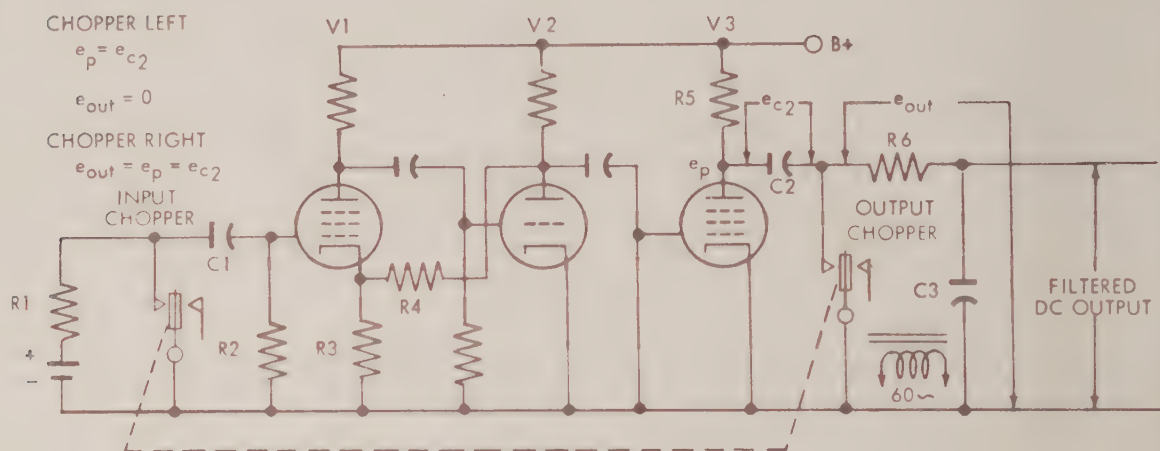


FIGURE 3-3

Its purpose is to convert low level DC to AC for stable amplification, amplify it, and reconvert it to DC. The plate decoupling and other circuits that do not directly affect amplification and rectification are not included. For the sake of clarity, a synchronously driven output chopper will be used to describe operation of the chopper amplifier, although in the Model 202B a driven crystal diode system is used to change the AC back to DC after amplification.

In Figure 3-3 the DC signal to be amplified is represented schematically by a battery in series with a resistance, connected to provide a positive input signal. There are two possible positions of the chopper poles at the input and output of the amplifier; poles left and poles right. With the poles left, the input voltage is grounded by the input chopper and the input to the first stage is zero. With no input voltage, assume a quiescent plate voltage of 100 volts for the last stage. Then, with the output chopper pole left, there is zero output because the junction of C2 and R6 is grounded, and C2 is charged through R5 to the plate voltage (e_p) of 100 volts. When the input chopper pole goes right, an input of the polarity shown in Figure 3-3 is applied through C1 to the grid of the first stage. This results in a decrease in the plate voltage of the first stage, an increase in the plate voltage of the second stage, and a decrease in the plate voltage of the third stage. Assume that the plate voltage of the last stage drops to 90 volts. When the output chopper pole is thrown to the right, C2 is no longer connected to ground. An output voltage is produced which is equal to the voltage that is now on the plate minus the voltage that C2 was charged to just prior to the chopper pole being thrown right. If C2 is charged to a nominal 100 volts and the plate voltage drops to 90 volts because of the positive input signal, the output is then ideally a square wave equal to -10 volts.

Although the input signal is positive with respect to ground this DC level is lost through capacitive coupling, and, except for an initial transient condition, the plate voltage of the last stage will vary both above and below the quiescent DC value. Figure 3-4 shows input and plate waveform as they would appear initially, and after several seconds.

INITIAL WAVEFORMS

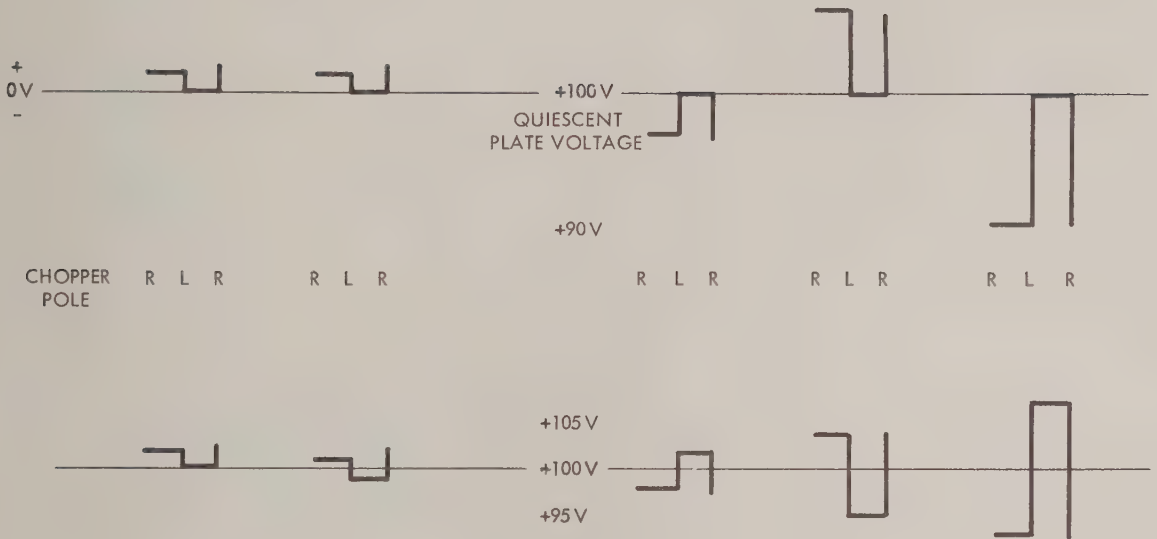


FIGURE 3-4

The voltage variation appearing at the plate of V3 would, after passing through C2, vary equally above and below ground potential, giving an average DC output of zero without further treatment. To obtain a significant DC output at the junction of C2-R6, an output chopper must be used. Figure 3-5 shows the effect of the output chopper on the output waveform at the junction of C2-R6.

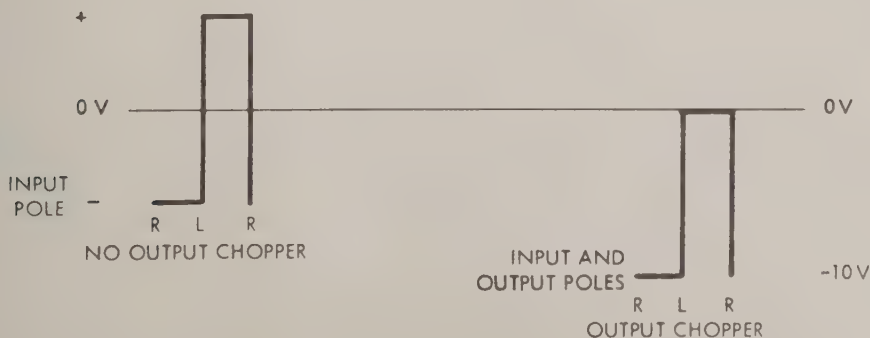


FIGURE 3-5

Figure 3-5 shows that the output chopper serves to clamp the top of the output square wave as described to ground. This is accomplished as follows: When the chopper pole goes left, the plate voltage of the last stage will rise to +105 volts, and C2 will charge to +105 volts, being connected between plate and ground. The output voltage will be zero because the junction of C2 and R6 is grounded. When the chopper poles go right again, the plate voltage of V3 will decrease from +105 to +95, and, since C2 has no quick discharge path, the output voltage, which was zero, will drop to -10 volts. Thus the output voltage is, again, equal to the plate voltage present when the output chopper pole is to the right minus the voltage that C2 was charged to just as the output chopper pole broke away from the left contact. The voltage across C2 closely follows the plate voltage of V3. This is because C2 has a relatively fast charge path through R5 and the chopper, and a relatively slow discharge path through R6, compared to the half-period of the chopper frequency. Because of this, C2 is unable to discharge to the point where gain would be affected. It thus becomes apparent that by means of the chopper amplifier, a pulsating DC output is obtained, which is proportional to but larger than the DC input.

Note that the DC gain of the chopper amplifier is less than AC gain. If the negative pulsating DC appearing at the junction of R6-C2 varies from zero to minus 10 volts, then its average DC value is minus five volts. Thus, in this case the DC gain is half the AC gain. This is the minimum loss possible, and in a practical three-stage chopper amplifier, a DC input to DC output gain 10 to 12 db below the AC gain is to be expected.

The output of the chopper amplifier is filtered by a filter designated R6 and C3 in Figure 3-3, the time constant of which is long compared to a half-period of chopper frequency. The filter actually used in the Model 202B is more complex. In the Model 202B, with no signal applied and with the AC amplifier balanced, there is, of course, no output at the filter. With maximum plus DC signal applied for any range there is a negative DC output of between 0.1 and 0.25 volt depending on amplifier load, with an AC sawtooth ripple of approximately 0.7 volt, when measured on an averaging type voltmeter.

Note that with the three stage AC chopper amplifier described a phase reversal has taken place so that a positive input voltage produces a negative output voltage. However, the DC amplifier which follows produces an additional phase reversal for an overall positive gain with the polarities described. Had the input to the chopper amplifier been negative instead of positive, the direction of all waveforms would have been reversed. The plate voltage on the output stage would have been higher than the voltage of C2, during the period when the output chopper was to the right. Therefore, the chopper output voltage, which is equal to the plate voltage of V3 minus the voltage on C2 at the time the output chopper switches from left to right, would have been positive. Again, the DC amplifier would give an additional phase reversal so that a negative input voltage would give a negative indication on the meter. Thus, it is seen that with a DC voltage applied to the chopper amplifier described, a larger proportional inverse voltage appears at the chopper output which, when further amplified by the following DC amplifier, gives a DC output directly proportional to the DC input.

Because of certain design considerations, a driven diode system using 3U1 diodes is used in the Model 202B, instead of the synchronous output chopper, to change AC back to DC after amplification. The method of utilizing diodes to replace the output chopper is illustrated in Figure 3-6. The function of the diodes is similar to that of the output chopper.

When the polarity of the driving voltage is as indicated in Figure 3-6, maximum conduction takes place through the diodes and point "x" is essentially at ground. When the polarity is the reverse of that indicated, point "x" is isolated from ground. By proper phasing of the diode AC voltage supply and the AC voltage which drives the input chopper, the diodes are in effect synchronized with the input chopper. By using sufficient driving voltage across the diodes, plate resistance is made much lower than would be the case with more conventional rectifiers, and a linear relationship between applied AC and output DC pulses is obtained throughout the range of applied voltage. Also, proportional inverse DC output is obtained regardless of the polarity of the amplifier DC input voltage.

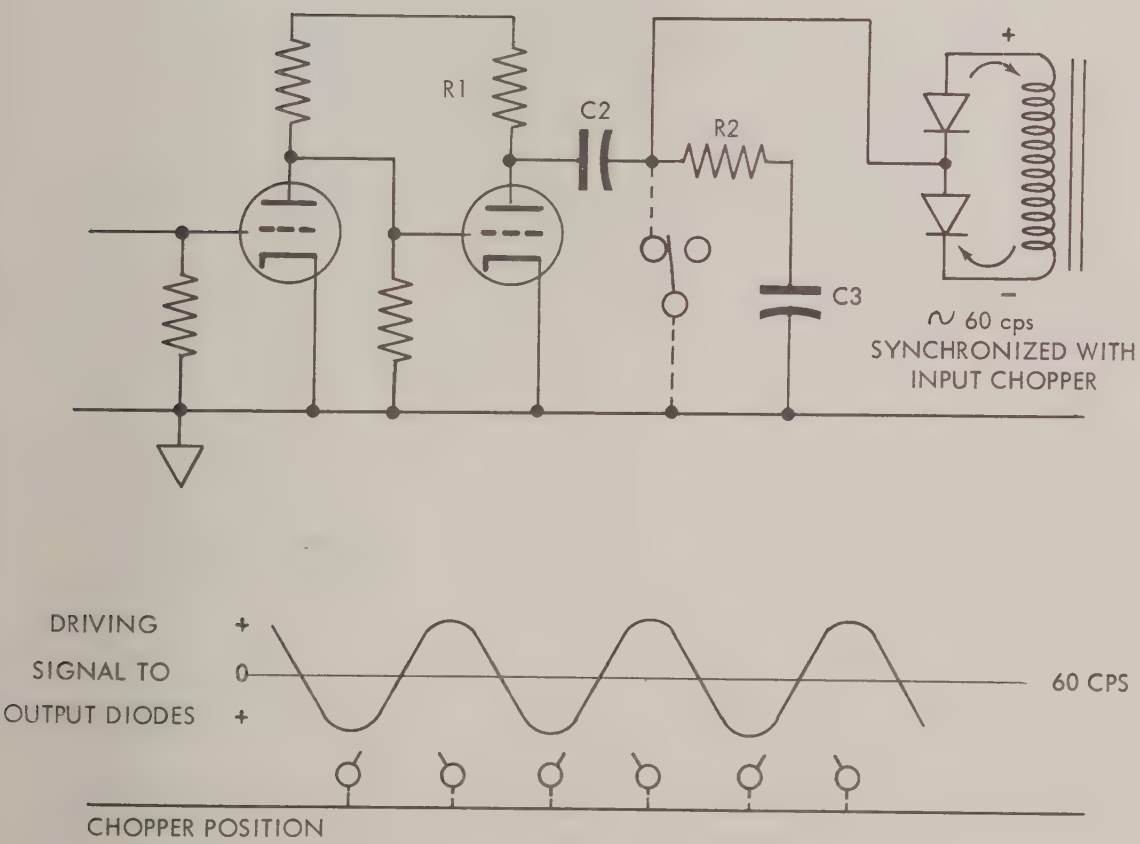


FIGURE 3-6

3.3.3 The DC Amplifier

As has been stated, the purpose of the chopper amplifier is to prevent drift and other micro-effects due to grid current, component and voltage changes, etc. However, after a number of chopper stages have brought the signal up to a point where the signal to noise level is more favorable, circuit economy demands that a direct coupled DC amplifier be used.

The two-stage DC amplifier in the Model 202B consists of a triode amplifier and a cathode follower. A neon bulb is used in the interstage divider to minimize gain loss, since it has low dynamic impedance with a relatively large DC voltage drop. R54, the DC balance control, sets the DC operating conditions in the amplifier, and the chopper amplifier is not required to furnish a steady bias voltage. The Thyrite resistor across the output and a plate resistor on the cathode follower limit the output voltage and current.

Capacitive feedback is connected between the input and output of the DC amplifier. The purpose of this feedback is to decrease the necessary size of the filter capacitor, to make system response time independent of DC amplifier gain variations, and to minimize the effects of internal disturbances in the DC amplifier.

3.3.4 The Feedback Circuit

In Section 3.2 the general expression for the gain of a feedback amplifier was developed. The application of this theory to a chopper amplifier will now be treated in detail. It will be shown that the gain of the chopper amplifier is $1/\beta$, as was the case for ordinary AC amplifiers.

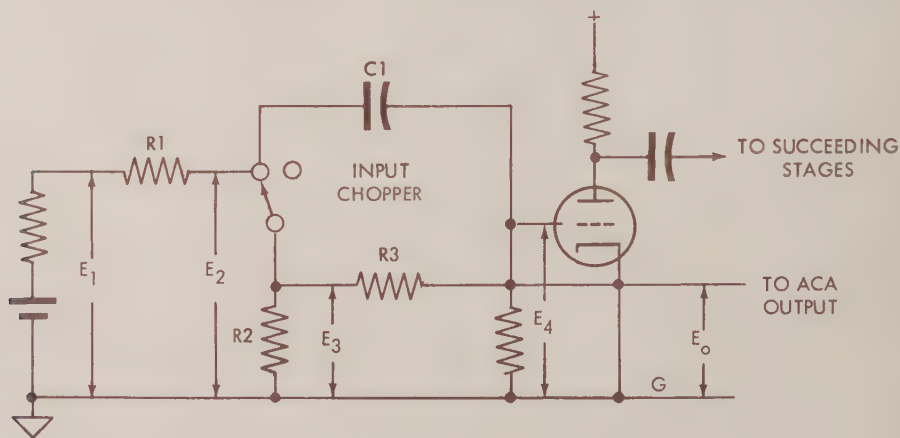


FIGURE 3-7

In Figure 3-7 let

E_1 = DC input signal to be measured

E_2 = DC signal plus feedback signal

E_3 = feedback signal from output attenuated through R_3

E_4 = peak-to-peak AC component of input (E_1) plus feedback (E_3)

E_o = output voltage.

Assume E_1 to be +10 volts. E_3 , the feedback voltage, is out of phase with E_1 and also less than E_1 as the feedback is less than 100%. Assume E_3 to be -5 volts. Then, with the chopper pole to the right E_2 is equal to E_1 . Therefore, as the chopper operates, E_2 varies between E_1 (+10) and E_3 (-5). The difference voltage of 15 appears across resistor R_1 .

The voltage at E_2 has a DC component as it swings between +10 and -5. This DC component is blocked by C_1 and so at E_4 the 15 volt swing varies plus and minus 7.5 volts from ground. This 15 volt square wave input across E_4 is the difference between E_3 and E_1 .

$$E_4 = E_1 - E_3 \quad (1)$$

Substituting the arbitrary values used for explanation,

$$E_4 = 10 - (-5) = 15 \text{ volts.}$$

Solving equation (1) for E_1 ,

$$E_1 = E_3 + E_4 \quad (1a)$$

The fraction of the output voltage fed back (β) appears at the junction of output voltage divider resistors R_2 and R_3 .

The feedback voltage may be stated as:

$$E_3 = \beta E_o \quad (2)$$

where

E_3 = feedback voltage

β = the fraction of the output voltage being fed back

E_o = output voltage

E_o is equal to the gain of the amplifier without feedback (K) times the AC input, (E_4).

$$E_o = K E_4 \quad (3)$$

where

E_o = output voltage to DC amplifier

K = gain of the amplifier without feedback

E_4 = AC input to amplifier

Therefore,

$$E_3 = \beta K E_4 \quad (4)$$

The net gain of the system is

$$A_n = \frac{E_o}{E_1}$$

where

A_n = net gain

E_o = output voltage

E_1 = input voltage

but

$$E_1 = E_3 + E_4 \quad (1a)$$

$$E_3 = \beta K E_4, \quad (4)$$

and

$$E_o = K E_4 \quad (3)$$

Therefore,

$$A_n = \frac{E_o}{E_1} = \frac{K E_4}{E_3 + E_4} = \frac{K E_4}{\beta K E_4 + E_4} = \frac{K E_4}{E_4 (\beta K + 1)} = \frac{K}{1 + \beta K}, \quad (5)$$

and if K is much greater than 1,

$$A_n \cong \frac{K}{\beta K} \cong \frac{1}{\beta} \quad (6)$$

Since feedback is obtained from the output by tapping off a portion of the output voltage at the junction of R_2 and R_3 , the feedback fraction (β), and therefore the net gain (A_n), may be expressed in terms of resistor sizes proportional to the voltage drops across them.

Thus,

$$\beta = \frac{R_2}{R_2 + R_3} \quad (7)$$

where

β = feedback fraction

Substituting in (6)

$$A_n \cong \frac{1}{\beta} = \frac{1}{\frac{R_2}{R_2 + R_3}} = \frac{R_2 + R_3}{R_2} \quad (8)$$

where

A_n = net gain

Thus it is seen that by making the gain sufficiently large so that βK (the feedback factor) $\gg 1$, the gain of the system depends only upon the ratio of the resistors of the feedback network and can be maintained at the same accuracy as the accuracy of resistors R_2 and R_3 in Figure 3-7

Feedback acts to increase the input impedance. This can be shown by considering the effect of feedback on the apparent input DC resistance seen by E_1 in Figure 3-7. The input current which flows without feedback (chopper pole right) is:

$$i_{wo} = \frac{E_1}{R} \quad (9)$$

where

i_{wo} = input current without feedback

E_1 = input voltage

R = apparent DC resistance.

With chopper pole left, the voltage which appears at the input (i.e. between left chopper contact and ground) is composed of E_1 , the input voltage, and E_3 , the feedback voltage. Since the feedback voltage is of opposite polarity and less than the input voltage, the total voltage with pole left is equal to input minus feedback voltage: E_1 minus E_3 . Therefore, the input current which flows with feedback (chopper pole left) is:

$$i_{wf} = \frac{E_1 - E_3}{R} = \frac{E_1 - E_2}{R} \quad (10)$$

since with chopper pole left, $E_3 = E_2$

As feedback increases, the difference between opposing voltages E_1 and E_3 decreases. Consequently, current decreases, and effective impedance increases.

Thus with feedback, the effective input impedance is increased.

The ratio of input impedance with and without feedback may be expressed as:

$$\frac{Z_{wf}}{Z_{wo}} = \frac{i_{wo}}{i_{wf}}$$

where

Z_{wf} = apparent input impedance with feedback

Z_{wo} = apparent input impedance without feedback

i_{wo} = input current without feedback

i_{wf} = input current with feedback

Inserting (9) and (10) the impedance increase ratio becomes

$$\frac{Z_{wf}}{Z_{wo}} = \frac{i_{wo}}{i_{wf}} = \frac{\frac{E_1}{R}}{\frac{E_1 - E_3}{R}} = \frac{E_1}{E_1 - E_3} \quad (11)$$

Inserting (1), (1a), and (4) in (11), the impedance increase ratio becomes

$$\frac{Z_{wf}}{Z_{wo}} = \frac{E_1}{E_1 - E_3} = \frac{E_3 + E_4}{E_4} = \frac{\beta K E_4 + E_4}{E_4} = \frac{E_4(1 + \beta K)}{E_4} = \beta K + 1 \quad (12)$$

As before, if the feedback factor, (βK) , $\gg 1$, then

$$\frac{Z_{wf}}{Z_{wo}} \cong \beta K \quad (13)$$

Just as the feedback factor increases the input impedance, it may be shown that it acts in the same manner to reduce the output impedance.

In a typical case, the forward gain factor (K) may be as much as 3×10^6 , and the fraction fed back (β) may be as large as 3.3×10^{-3} . Thus, the feedback factor (βK) may be as much as 16,000, and large input impedances are possible. Note, however, that the input impedance is not a fixed value as is the net gain, but depends on K , the forward gain of the system and hence is subject to the normal vagaries of an electronic amplifier without feedback. It is sufficient, however, that input impedance to the chopper be made much larger than the impedance of the attenuator which it shunts. With the large but varying chopper input impedance in parallel with a much lower constant value attenuator resistance, the input to the instrument is then merely the resistance of the (nearly) unloaded attenuator. It is because this is actually achieved in the 202B that it is possible to place a specification of constant, known, input impedance on the instrument.

3.4 CIRCUIT DETAILS

The schematic diagram of the instrument will be found in the appendix.

3.4.1 Input and Range Switching Circuit

The voltage to be measured is applied to the isolation probe which is used to minimize capacitive loading on the circuit being measured. The probe contains a 1 megohm resistor. The signal being measured is conducted through the isolation probe resistance and a shielded lead to the input attenuator.

The 14 position, three section, voltage range switch (S2A, B, C) is shown in the upper left portion of the schematic diagram. On the first three ranges, the feedback of the system is varied by inserting feedback resistors R16 and R17. These resistors occupy the same position in the circuit as R_3 of Figure 3-7, and serve to increase gain on the 0.3, 1, and 3 mv ranges. On these ranges the gain of the amplifier is being varied rather than the input signal. This is necessary because of the extremely low energy input signals obtained on the lower ranges.

Amplifier gain may be determined by using equation (8) section 3.3.4, which refers to Figure 3-7.

$$A_n \cong \frac{R_2 + R_3}{R_2}$$

For example, by referring to the schematic diagram it may be seen that R_3 in equation (8) section 3.3.4, is comprised of amplifier resistors $R_{15} + R_{16} + R_{17}$ on the 300 μv range, and the R_2 in equation (8) section 3.3.4, refers to amplifier resistor R_{26} . Therefore, amplifier gain on the range is:

$$\frac{R_{15} + R_{16} + R_{17} + R_{26}}{R_{26}} = \frac{3694 + 7406 + 25930 + 10}{10} = 3704$$

This is a gain of approximately 70 db, including a 1 db divider loss on the lower ranges. On the 3 mv range, and higher, the gain is reduced to 370, or approximately 50db.

Above the first three ranges, sections A and B of the voltage range switch function as a step attenuator on the input signal and the gain of the system remains constant as fixed by R_{15} and R_{26} . The step attenuator is a 100 megohm divider comprised of R_3 through R_{14} , and R_{62} . This attenuator makes use of the system shown in S2A and B.

On the .3, 1, 3, and 10 mv ranges, R_{62} and R_5 through R_{14} form a voltage divider. The output is taken from the junction of R_{62} and R_{13} to ground for the first three ranges and between R_{12} and R_{13} for the 10 mv range. On the 30 mv range the divider consists of R_{62} and R_4 through R_{14} , with the output taken from the junction of R_{12} and R_{13} . On the 100 mv range, all the resistance has been inserted in the circuit, and on the higher ranges only the take off point is varied. Except for the lower voltage ranges, the input resistance of the voltage divider network is 100 megohm. On the lower ranges, input impedance is sacrificed to obtain low noise operation and stable input impedance, which is more important on the lower ranges than high input impedance. When signal is extremely small, the sensitivity is limited by thermal noise, no matter what circuit configuration is chosen.

3.4.2 The Chopper Amplifier

The chopper amplifier consists of chopper D1, capacitively coupled amplifier tubes V1 and V2, and the chopper diodes. The first stage is a special low-noise tube utilizing filtered DC filament voltage to maintain a low hum level. The second and third stages utilize a 6AW8 tube, and are triode and pentode respectively. V1 operates with reduced filament voltage and consequently may suffer appreciable gain variations due to line voltage fluctuations within the rated range. Schematic resistors R_{30} and R_{36} form a local feedback loop which, as shown in Paragraph 3.2, will cause the effect of gain variations in V1 to be negligible. Thus, overall system stability is maintained despite varying circuit conditions.

The signal to be measured is fed from the attenuator section to the input filter. The purpose of this filter is to reduce any 60 cycle signal which might be superimposed on the DC signal to be measured. When such an AC signal is present, the signal indicated at the output will not be the average value of DC, due to synchronism between the chopper sequence and the AC ripple.

The input filter employs three RC sections to provide a sharp cut-off rate above a few cycles per second. The maximum high-frequency attenuation is limited by R_{19} , R_{21} , and R_{23} . This allows a fraction of a fast input signal to drive the input rapidly, which provides good 60 cycle rejection without a substantial increase in response time.

After filtering, the signal is fed to the chopper through R_{24} , which corresponds to R_1 of Figure 3-7. The input chopper converts the DC signal to a proportional AC signal which is fed through two coupling networks, $C_8 - R_{27}$, and $C_9 - R_{29}$. Use of these networks reduce the effects, at the input, of rapidly varying grid current in V_1 . R_{36} provides feedback for gain stability, as does R_4 in Figure 3-3.

Two RC coupling networks consisting of $C_{16} - R_{43}$, and $C_{18} - R_{44}$ are used in the output stage of the ACA. This arrangement has two purposes. The first is to reduce DC leakage due to the high plate potential. The leakage resistances in conjunction with the 10 megohm resistors result in a very large attenuation factor. In addition the low frequency cut-off is more rapid, reducing the effects of low-frequency line transients. There is no appreciable effect on demodulation, since the two capacitors are equivalent to one having one-half the capacitance, and the 10 megohm resistors constitute a DC load. There is a difference in charge characteristic, however. Charge due to signal is divided equally, while C_{16} holds most of the charge due to nominal plate voltage. In the last stage of the ACA the chopper diodes develop an output which is the difference between V_{2b} plate voltage, and the charge on C_{16} and C_{18} . This voltage is applied to the filter at the input of the DCA. The filter output is a DC signal with some ripple. This ripple is due principally to hum. The internal gain of the 202B is so high that only a very small input signal (E' in of section 3.2) is needed to set the output level, except during transient conditions. It is not possible to see this signal clearly in the presence of normal hum. Only a small change in the symmetry of the hum may be noticeable.

3.4.3 The DC Amplifier and Output Circuit

The DCA utilizes a 6CG7 dual triode. One section is used as a conventional amplifier, the other as a cathode follower.

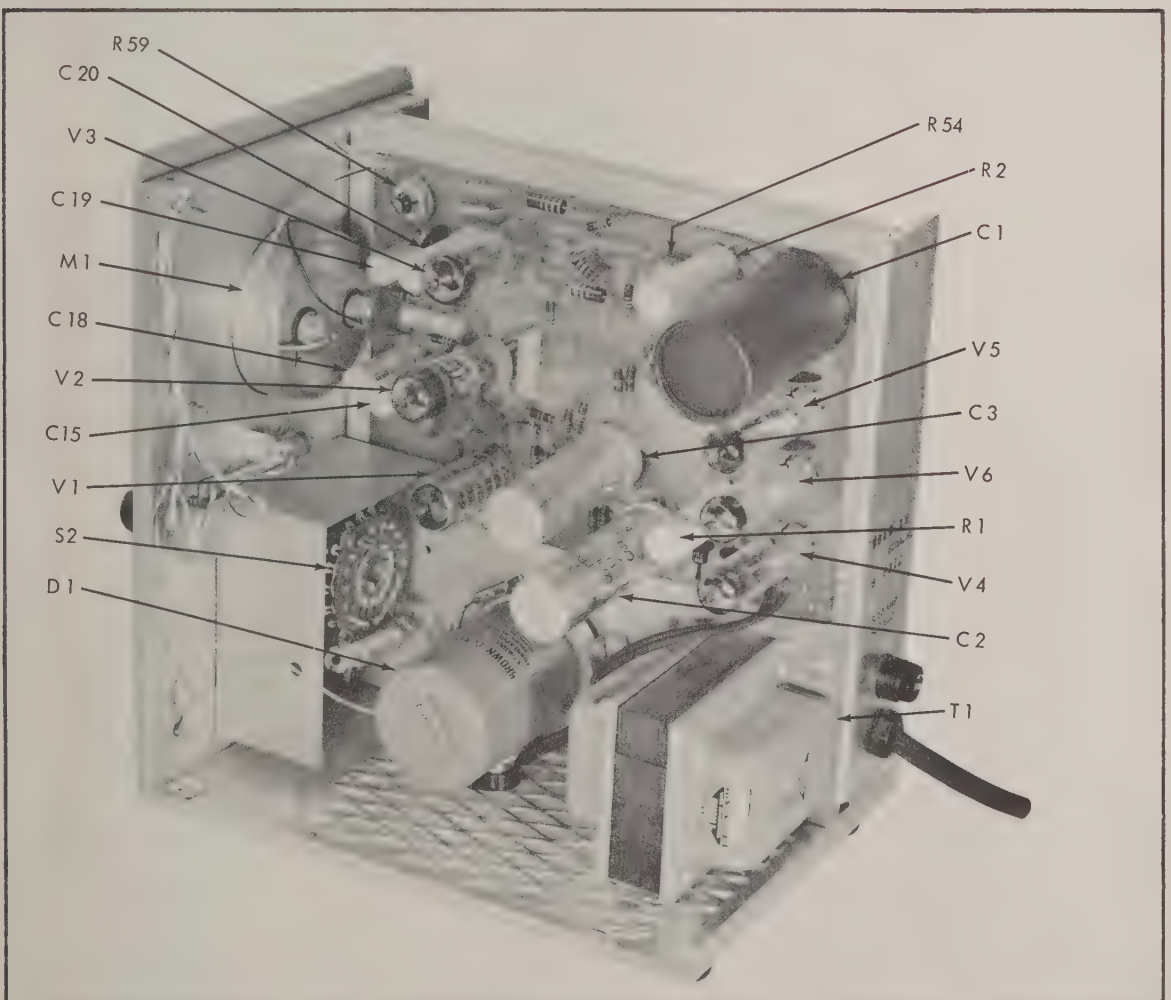
The meter is connected across the amplifier output in series with the proper multiplier and shunt resistance. R_{59} , a screwdriver adjustment, is provided for initial factory calibration. The output connector is for an external indicating device capable of handling plus or minus one volt maximum output signal, and presenting not less than a 1000 ohm load to the amplifier.

SECTION 4

MAINTENANCE

4.1 PARTS LOCATION

The instrument cover may be lifted off after removing the two screws at the rear and the four screws on the bottom. Figure 4-1 is a photograph for general orientation purposes. Figure 4-2 shows parts location on the component side of the large etched board. Figure 4-3 shows parts location on the filter board. Figure 4-4 shows test points on the printed circuit side of the etched board.



GENERAL COMPONENT ORIENTATION

FIGURE 4-1

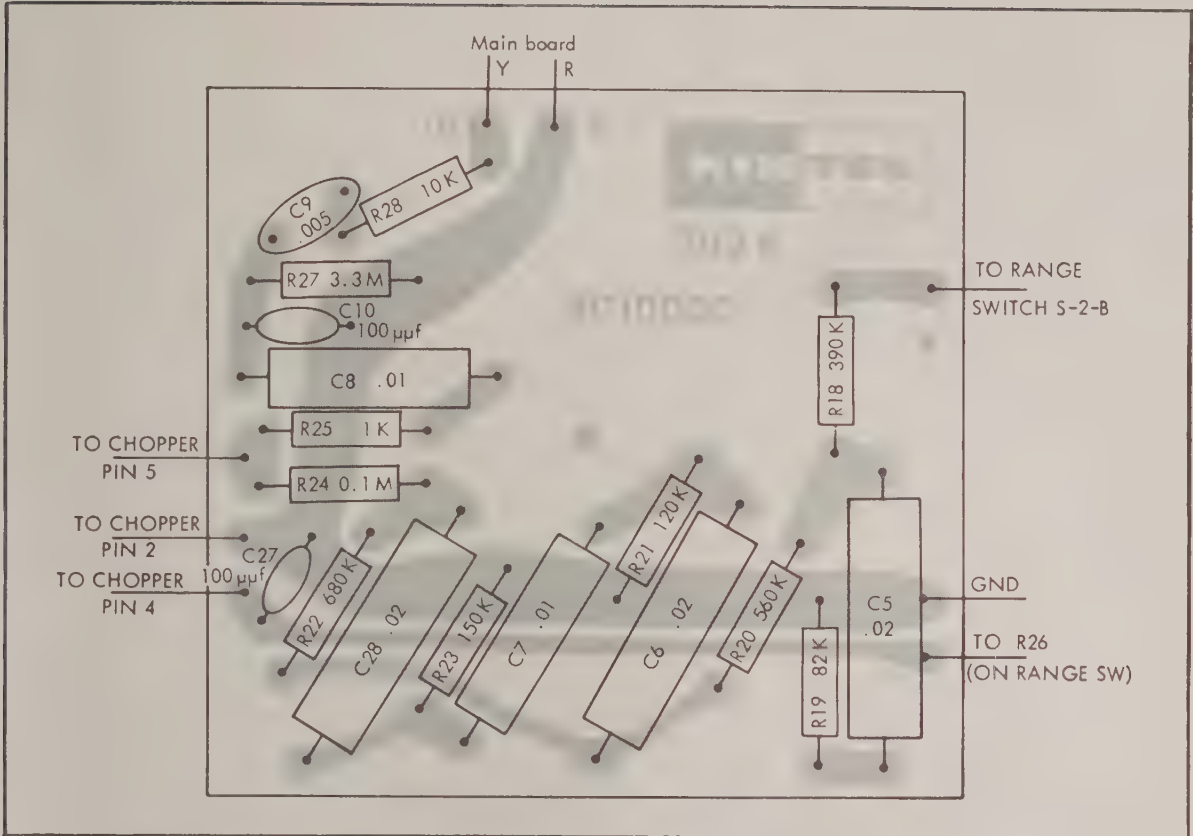


FIGURE 4-3 PARTS LOCATION ON FILTER BOARD

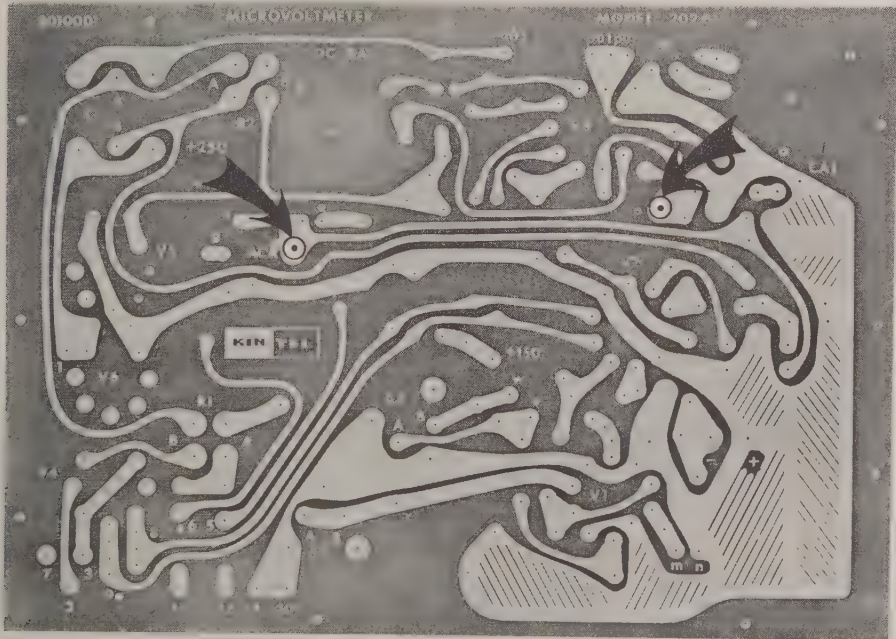


FIGURE 4-4 TEST POINTS ON ETCHED BOARD

4.1.1 Precautions

When any measurements are made in the process of servicing, the instrument must be shielded. Use a sheet-metal shield in close proximity to the area shown in Figure 4-5, and ground the shield to the chassis of the instrument. If the instrument is operated with the cover removed and without shielding, pickup from stray fields will overload the amplifier.

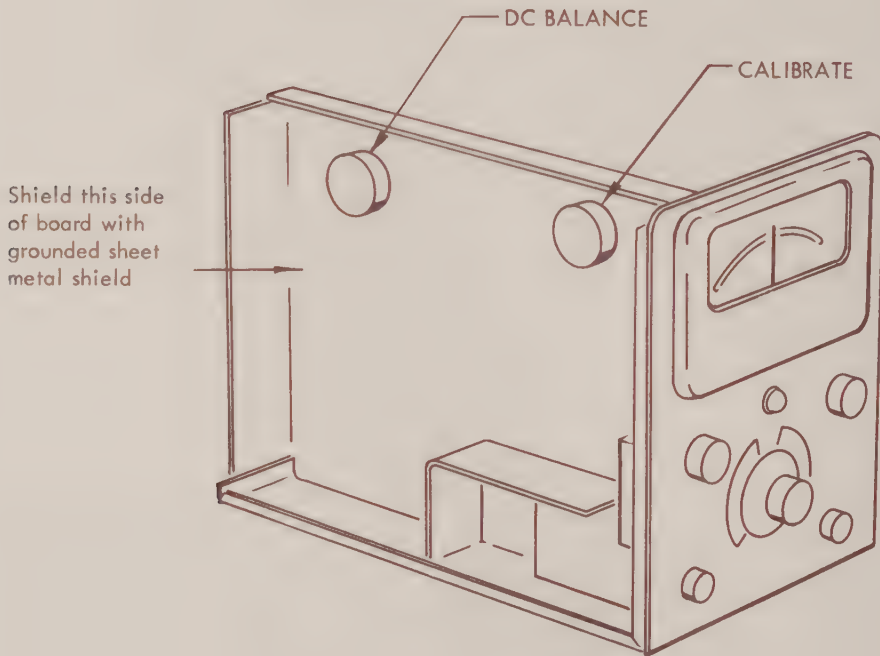


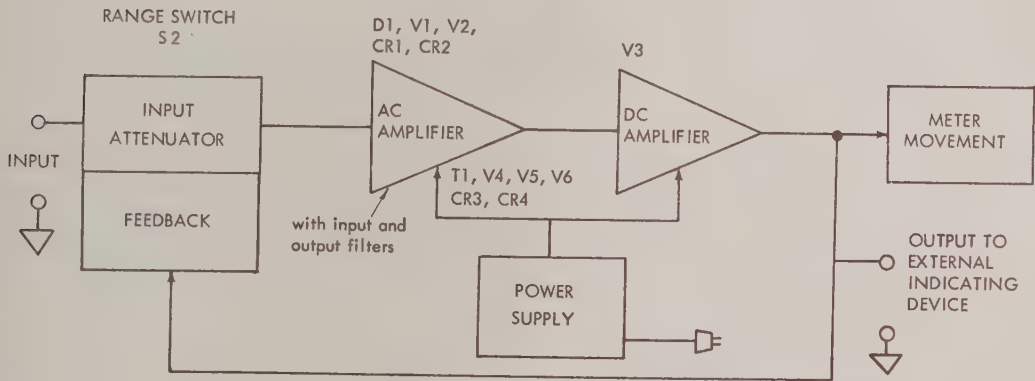
FIGURE 4-5

4.2 PREVENTIVE MAINTENANCE

The chopper and all tubes should be checked every 5000 hours of operation as a matter of routine. Electrolytic capacitors should be checked for leakage and correct capacity every two years. Note the use of a cardboard cover on the filter capacitor of the high voltage power supply. This cover acts as an insulator to prevent the capacitor case which is at -105 volts from constituting a shock hazard to the technician, and should not be removed. The instrument should not be placed in areas where temperature or humidity extremes exist. Acid fumes, salt spray, and other corrosives should be avoided.

4.3 TROUBLE SHOOTING PROCEDURE

There are a number of satisfactory means of pin-pointing troubles to the various stages as shown in Figure 4-6. These stages consist of the input attenuators, the feedback circuit, the AC chopper amplifier, the DC amplifier, the meter movement, and the power supply. However, as with any electronic device the most common sources of trouble are weak or defective tubes, or moving parts. Therefore it is usually advantageous to check the tubes and chopper before resorting to more complex methods of isolating troubles. Tubes and chopper may be checked by substituting units known to be satisfactory. For tubes, a good transconductance tester may also be used, but in the final analysis the most practical check of a tube's worth is whether or not it works in the circuit.



BLOCK DIAGRAM OF MODEL 202B

FIGURE 4-6

4.3.1 AC Amplifier

In the case of a chopper, the following procedure might be used:

A non-operative chopper causes the meter to peg regardless of input signal. It may be determined if the chopper is operating by touching its case to feel the vibration. If the chopper is not operating, the 6.3V AC input should be checked at the chopper plug.

A chopper may vibrate, however, and still be defective, as evidenced by random drifting of the meter needle to the right or left, and erratic zero set. A sharp mechanical jolt will cause a defective chopper to change the meter zero position. A satisfactory chopper under shock test will cause some meter offset, but the meter will shortly return to its previous stable position.

4.3.2 Power Supply

After determining that chopper and tubes are satisfactory, and if the instrument is completely inoperative, remaining at zero on all ranges, the trouble is probably in the power supply. After removing the instrument case, all power supply voltages and DC ripple may be checked from the indicated points on the printed circuit side of the etched circuit boards on which the tubes are mounted. If no DC output is present, the input AC voltage to the supply should be checked. If these voltages are present, but are not correct, the filter capacitors should be checked for capacity and for leakage.

4.3.3 Meter Circuitry

If the power supply voltages are satisfactory and the meter is completely dead, the meter circuitry should be checked by measuring the output of the instrument at the output terminals with a 1 volt or higher DC voltmeter known to function. If the instrument meter is found to be inoperative after checking resistors R57, R58, and R59, it should be replaced with an identical movement if proper calibration is to be maintained. If an external meter fails to give indication, work back toward the amplifier input from the meter to determine the point where the signal disappears. Keep in mind the nature of the signal at various points in the circuit, and choose the appropriate setting and range on the test instrument being used.

4.3.4 Feedback and Attenuation

If the instrument fails to operate properly over a particular range, the corresponding components in the range switching circuit should be checked. For example, if the instrument fails to operate properly on all ranges above 10 mv, it is probable that input attenuator resistor R4 is defective. Isolation of the probable source of trouble may be accomplished in a similar manner whenever faulty operation of the instrument is confined to a particular range or group of ranges.

An oscillating amplifier may cause the meter to give no indication, swing rapidly back and forth, or peg, or swing sufficiently to peg on each swing, depending on the conditions producing it. If the instrument oscillates, look for trouble in the feedback circuits. Without feedback the amplifier gain becomes so high that unstable operation results. Oscillation may be checked for with an oscilloscope. A continuity check of feedback resistors R15, R16, R17, and R26 is a good starting point for locating a trouble of this type. The feedback capacitor C20 in the DC amplifier, or the feedback network in V1 of the AC amplifier, may be defective.

To check continuity of the input attenuator turn off the instrument and remove the chopper. Check resistance from the input probe to ground with an ohmmeter capable of measuring 100 megohms accurately. With the voltage switch on the 10 mv range and below the resistance is 10 megohms, on the 30 mv range, 30 megohms, and on the 100 mv range and above, 100 megohms. Any appreciable variation from these figures indicates attenuator trouble.

4.3.5 DC Amplifier

The balance control in the DC amplifier is R54. It should be adjusted after adjusting R52 as follows: Allow a warm-up period of at least 15 minutes. With the Model 202B set on the 3 mv range or higher and the probe shorted, connect a DC VTVM having 11 megohms or more input resistance from point "p" to ground and adjust R54 for zero volts. This is an average value, as some bounce will always be evident. Meter calibration resistor R59 should not be adjusted with the possible exception of a meter change.

Since the signal normally applied to the input chopper is not of sufficient amplitude to permit observation of the input chopper dwell time, an artificially large signal must be introduced. This may be accomplished by switching the instrument to the lowest range and connecting a 1.5 volt flashlight cell across the input terminals. The dwell time of the input chopper may then be observed by connecting the oscilloscope input probe to pin 9 (point "m") of V1. To avoid a DC offset from the bias cell, use the oscilloscope on AC coupling. The waveform should reveal a period of zero voltage occurring approximately 50% of the total period. This occurs during the time that the chopper contacts are grounding the input. The grounded period is followed by a period when the chopper contacts are open. This period will generally indicate a large amount of hum which should be fairly consistent and free of excessive spikes, as shown in Figure 4-8.

In the Model 202B the driven diodes CR1 and CR2 may be checked by shorting the input probe, and rotating the AC amplifier detector balance control R52 (zero control) while observing the ACA output at the test point. The waveforms shown in Figure 4-7 should be obtained. Note that the control is non-symmetrical and also that the hum during the chopper contact open time may have different characteristics than shown in Figure 4-7. To zero adjust the ACA, short the input lead and adjust R52 for an ACA output of zero.

Some care must be used in selection of the Z729 chopper amplifier input tube. The most common troubles encountered with Z729 tubes are either low gain or filament leakage. In the case of the former, sluggish performance will result. Filament leakage will cause 120 cycle ripple to appear at the ACA output (marked "ACA" on the etched board). This hum usually results in a pronounced zero shift.

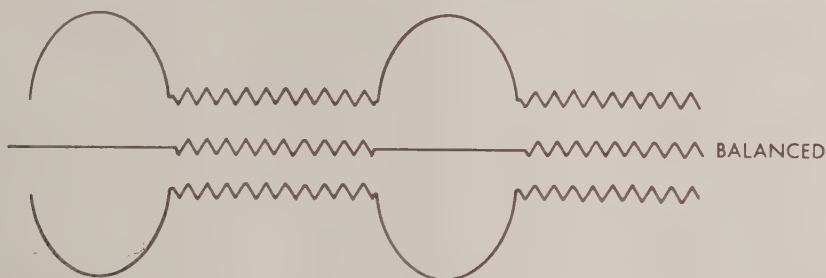


FIGURE 4-7

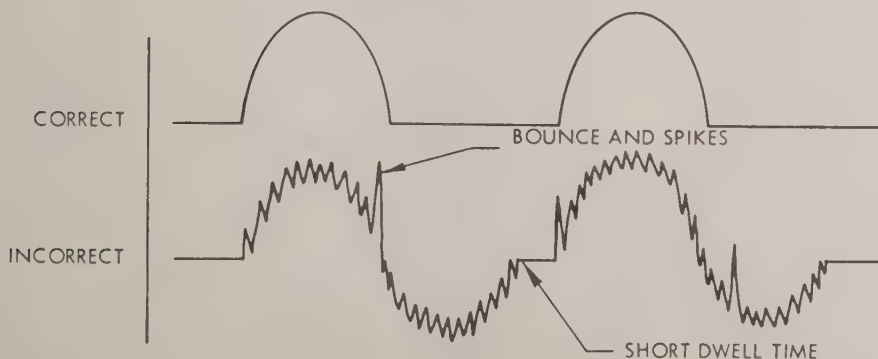


FIGURE 4-8

MODEL 202B

MICROVOLTMETER

PARTS LIST

Job 8010

RESISTORS		KIN TEL PART NO.	RESISTORS		KIN TEL PART NO.
+ R1A	(* 23Ω 5w Claro D8KS	5110002	R36	330K 1/2w	4101351
+ R1B	(* 500Ω 5w Claro D8KS	5110002	R37	1.5 meg 1/2w	4101359
+ R2A	(* 2.5K 5w Claro D8KS	5110001	R38	1 meg 1/2w	4101357
+ R2B	(* 5K 5w Claro D8KS	5110001	R39	390K 1/2w	4101352
" R3	*70 meg 2w 1/2%	4806024	R40	3.3 meg 1/2w	4101363
" R4	* 20 meg 1w 1/2%	4806023	R41	39K 1/2w	4101340
" R5	* 630Ω 1/2w 1/2%	4705387	R42	82K 1w	4301574
" R6	* 1.8K 1/2w 1/2%	4705389	R43	10 meg 1/2w	4101369
" R7	* 6.3K 1/2w 1/2%	4706020	R44	10 meg 1/2w	4101369
" R8	* 18K 1/2w 1/2%	4705391	R45	2.7 meg 1/2w	4101362
" R9	* 63K 1/2w 1/2%	4705394	R46	270K 1/2w	4101350
" R10	* 180K 1/2w 1/2%	4705395	R47	2.7 meg 1/2w	4101362
" R11	* 630K 1/2w 1/2%	4705396	R48	39K 1/2w	4101340
" R12	* 1.8 meg 1/2w 1/2%	4706025	R49	39K 1w	4301570
" R13	* 6.3 meg 1w 1/2%	4806022	R50	470Ω 1/2w	4101317
" R14	* 270Ω 1/2w 1/2%	4705386	R51	39K 1/2w	4101340
" R15	* 3.694K 1/2w ±0.25%	5210001	R52	50K 2w A-B Pot	5010054-7
" R16	* 7.406K 1/2w ±0.25%	5210001	R53	56K 1w	4301572
" R17	* 25.93K 1/2w ±0.25%	5210001	R54	100K 2w A-B Pot	5010015-9
	Cinema SW-3BE		R55	390K 1/2w	4101352
R18	390K 1/2w	4101352	R56	33K 1w	4301569
R19	82K 1/2w	4101344	R57	* 4.7K 1/2w 1/2%	4710002
R20	560K 1/2w	4101354	R58	* 2.7K 1/2w 1%	4710001
R21	120K 1/2w	4101346	R59	1K 2w A-B Pot	5010013-9
R22	680K 1/2w	4101355	+R60	82Ω 1/2w	4101308
R23	150K 1/2w	4101347	+R61	120Ω 1/2w	4101310
R24	1 meg 1/2w	4101357	≠R62	* 1 meg 1/3w 5%	4207343
R25	1K 1/2w	4101321	+R63	270Ω 1/2w	4101314
R26	* 10Ω 1/2w .1%		+R64	270Ω 1/2w	4101314
	Cinema SW-1AE	4707095	R65	18K 1w	4301566
R27	3.3 meg 1/2w	4101363			
R28	10K 1/2w	4101333			
R29	15 meg 1/2w	4101371		* Recommended Spare	
R30	150Ω 1/2w	4101311			
R31	390K 1/2w	4101352		+ Power Supply	
R32	1.8 meg 1/2w	4101360			
R33	47K 1/2w	4101341		" Attenuator	
R34	18K 1/2w	4101336			
R35	100K 1/2w	4101345		≠ Probe Assembly	

* Recommended Spare

+ Power Supply

" Attenuator

≠ Probe Assembly

PARTS LIST (Continued)

MODEL 202B - MICROVOLTMETER

CAPACITORS		KIN TEL PART NO.	MISCELLANEOUS		KIN TEL PART NO.
+ C1A/B	* 40/40 μ f 500v	510006	BT1	*Bias Cell RM625T	1804158
+ C2A/B	* 1000/1000 μ f 15v	510007			
C3A/B	* 80/40 μ f 150v	510005	CR1	* Diode 3U1	3506774
" C4	100 μ f 1500v Mica Cap	707785	CR2	Diode 3U1	3506774
C5	.02 μ f 200v Mylar 620	607251	+ CR3	* Diode 1N91	3506751
C6	.02 μ f 200v Mylar 620	607251	+ CR4	Diode 1N91	3506751
C7	.01 μ f Ceramic Disc	401056			
C8	.01 μ f Ceramic Disc	401056	D1	* Brown Chopper SS-8899KC	6306855
C9	.005 μ f Ceramic Disc	401054			
C10	100 μ f Ceramic Disc	401022	F1	* Fuse .3amp. SloBlo	1710027
C11	.25 μ f 200v Mylar 620	606278			
C12	.002 μ f Ceramic Disc	401048	I1	Neon Lamp NE 2	1704151
C13	.01 μ f Ceramic Disc	401056	I2	* Pilot Lamp No. 47	1704149
C14	.1 μ f 200v Mylar 620	606443			
C15	.25 μ f 200v Mylar 620	610001	L1	25 μ h Choke Coil	2306773
C16	.1 μ f 400v Mylar 620	607317			
C17	.002 μ f Ceramic Disc	401048	M1	Meter 150-0-150 μ a	3010001
C18	.1 μ f 200v Mylar 620	606443			
C19	.05 μ f 200v Mylar 620	607318	RT1	* Thyrite 432 BNR-18	4904225
C20	.25 μ f 200v Mylar 620	610001			
C21	.001 μ f Ceramic Disc	401046	S1	SPST Rotary Switch	
C22	100 μ f Ceramic Disc	401022		250v - 3A No. 570	6206247
C23	.01 μ f 200v Mylar 620	606740	" S2	14 Pos. 3 Pole Rotary Oak	
C24	.01 μ f 200v Mylar 620	606740		77016-L3	6210004
+ C25	.01 μ f Ceramic Disc	401056			
+ C26	.01 μ f Ceramic Disc	401056	T1	Transformer 8346	6507187
C27	100 μ f Ceramic Disc	401022			
C28	.02 μ f 200v Mylar 620	607251			

TUBES

V1	* Z729	7005715
V2	* 6AW8	7007419
V3	* 6CG7	7006354
V4	* 6X4	7002786
V5	* OA2	7302792
V6	* OB2	7302794

* Recommended Spare

+ Power Supply

" Attenuator

WARRANTY

WARRANTY: KIN TEL warrants the equipment manufactured by it to be free from defects of material and workmanship under normal use and service. In consideration thereof its obligation and liability under said warranty is limited to servicing or adjusting any instrument returned to its factory for that purpose upon its written instruction, and to make good at its factory any part or parts thereof, except tubes, transistors, fuses and batteries, which shall, within one year (Instruments), or ninety days (Television) after making delivery to the original purchaser, be returned by the original purchaser to KIN TEL with transportation charges prepaid, and which in KIN TEL's examination shall disclose to KIN TEL's satisfaction to have been thus defective. No warranties other than those set forth in this section are given or are to be implied with respect to the equipment furnished hereunder.

For customer convenience, service departments are maintained throughout the United States by KIN TEL field-engineering representatives, where service is available both during and after the warranty period.



INDIVIDUAL INSTRUMENT RECORD
AND AUTHORIZATION FOR REPAIR

MODEL NO. _____ SERIAL NO. _____ CUSTOMER
PURCHASED FROM: _____ DATE PURCHASED: _____ P. O. NO. _____

SYMPTOMS NOTED: _____

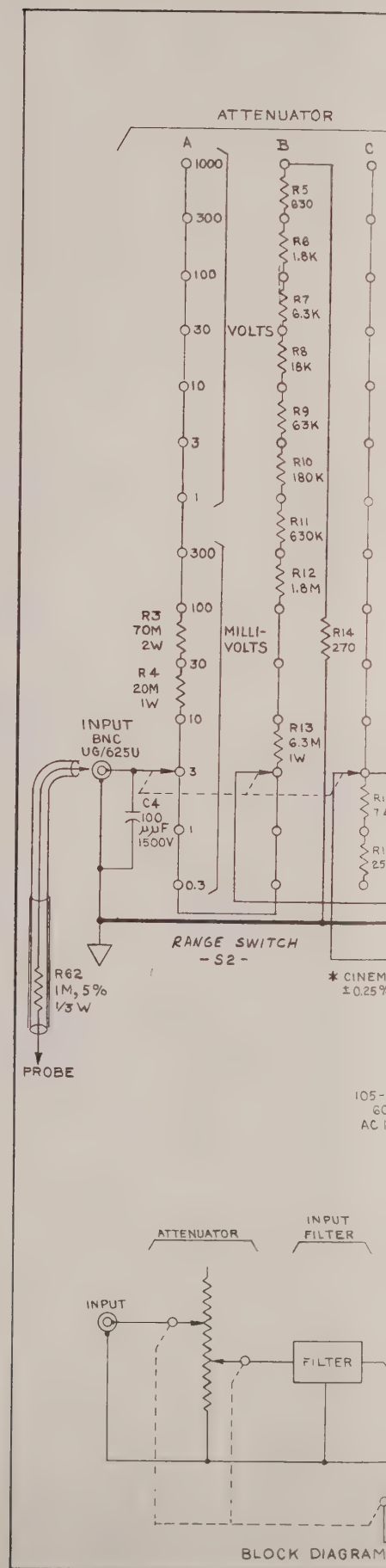
(If application entails environmental or other specific ambient conditions which may affect operation, please describe)*
REPAIR AUTHORIZED BY: (Person, Company and Date)** _____
SPECIFIC REPAIRS REQUESTED: _____

(If additional papers accompany this RECORD, please staple to this sheet. Back of this sheet may be used for further data)

SHIPPING INSTRUCTIONS FOR RETURN OF INSTRUMENT: _____

BALANCE OF THIS FORM TO BE COMPLETED BY REPAIR PERSONNEL ONLY	
REPAIR DATE: _____	REPAIR ORDER NO. _____ TECHNICIAN: _____
REPAIRS PERFORMED (Including any discrepancies noted): _____	

*If classified information affects repair status, state contact for KIN TEL Security Department.
**Repair must be authorized by KIN TEL or representative personnel and this form returned with instrument.



D1
BROWN CHOPPER
SS-8899-KC

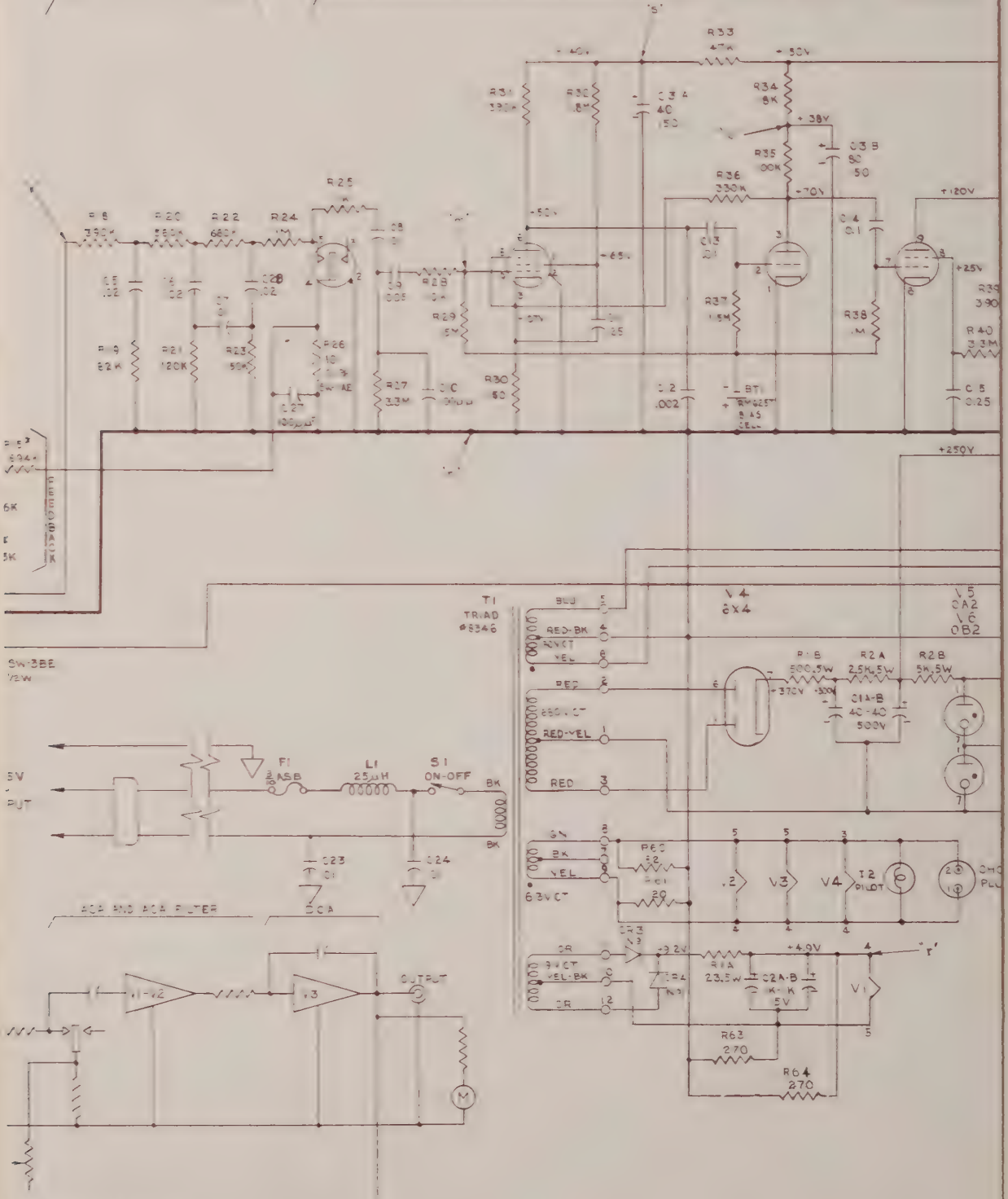
V1
Z729
1ST ACAMP

V2A
1/2 6AW8
2ND AC AMP

V2B
1/2 6AW8
3RD AC AMP

INPUT FILTER

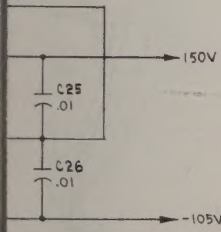
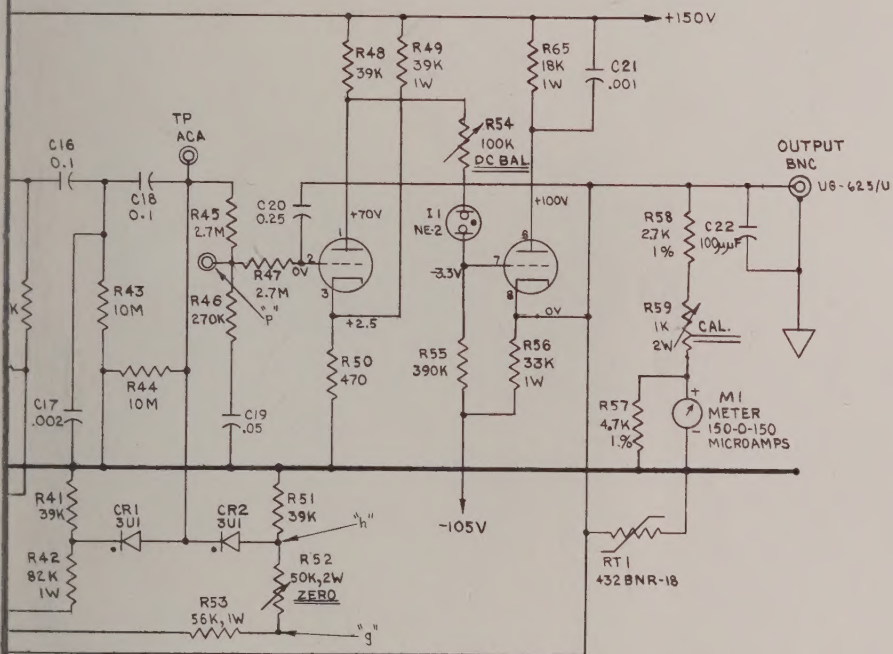
ACA AND ACA FILTER



LESS POWER SUPPLY

V3A
½ 6CG7
DC. AMP

V3B
½ 6CG7
CATHODE
FOLLOWER
DCA



UPPER
G

NOTES

1. VOLTAGES SHOWN ARE APPROXIMATE FOR NORMAL OPERATION AS MEASURED WITH AVTVM OF 100M INPUT RESISTANCE
2. LETTERS g, h, k, m, n, p, r, s, w REFER TO POINTS IN CIRCUIT WHICH ARE IDENTIFIED ON ETCHED BOARDS.

ALL RESISTORS K WATT
ALL RESISTANCES IN OHMS.
ALL CAPACITANCES IN MICROFARADS
UNLESS OTHERWISE SPECIFIED.

MODEL 202B DC MICROVOLT METER SCHEMATIC		DATE 7/30/56
DRAWN BY <i>[Signature]</i>		APPROVAL <i>[Signature]</i>
DESIGNING NO. 00010000		JOB NO. 0010
KIN TEL		327 DEPT.

8010000

